

Bonded Repair of Composite Airframe Structures

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Introduction

Composites have many advantages for use as aircraft structural materials including their high specific strength and stiffness, resistance to damage by fatigue loading and resistance to corrosion. Thus, extensive use of these composites should reduce the high maintenance costs associated with repair of corrosion damage normally associated with conventional aluminum alloys. Similarly, costs associated with the repair damage due to fatigue should also be substantially reduced, since composites do not, in general, suffer from the cracking encountered with metallic structures.

However, maintenance costs associated with repair of service impact damage is expected to increase, since most composites are essentially brittle in nature. Even modest impacts can lead to internal damage in the form of delaminations, which results in the marked strength reduction, particularly under compression loading. The impacted area may not be apparent from surface examination because of the absence of permanent deformation of the surface. Figure (1) shows some examples of the types of damage encountered in service.

The ongoing project will investigate the effects of multiple bonded repair variables and characterize the strength of the repairs using various experimental methods to determine the effectiveness of the repair. Using these repair variables, the experimental results will also be utilized to validate available analytical techniques. The methods and repair procedures proposed by the Commercial Aircraft Composite Repair Committee (CACRC) will be utilized whenever possible and input will be provided to the FAA which can be used in general guidelines for bonded repair.

Program Objectives

The research program is divided into four tasks which focus on various following tasks describe the proposed scope of work. The partners involved in the proposed investigation are shown in Figure (2) along with primary role of the partner and national & international organization interface. All materials, fabrication and repairs will be supplied by the Boeing Company (Wichita) and/or airline CACRC members.

- ?? Task 1 - Validate repair methods using CACRC repair method
- ?? Task 2 - Data generation on repair variables (scarf ratio, core size, prepreg versus wet layup, various loading modes, impacted repairs)

- ?? Task 3 - Link to available NDE methods
- ?? Task 4 - Investigate available analytical methods and validate using data generated in Task 2

Tasks 1-3 will be primarily focused towards experimental testing which includes loading modes in tension, compression and shear. All coupons will be manufactured by Boeing and representative of production environment manufacturing. The main objective of task 1 will be the comparison of field repair techniques with repairs performed by the Original Equipment Manufacturer (OEM). Task 2 will consist of data generation for use in task 4 and task 3 will compare available NDE methods and develop specific levels of detectable of field repair methods with respect to laboratory methods.

The analytical task (task 4) will utilize coupons repaired with one-dimensional and two-dimensional repairs. The main objective of this task will consist of a validation of several of the analytical methods and will be integrated into ongoing work by the CACRC analytical task group. The model predictions will be compared with static strength tests performed under different loading modes (tension, compression, flexure and shear).

Considerations which will be addressed in validating the analysis methods :

- ?? Locate the damaged area and describe the damage with a drawing or sketch.
- ?? Understand the original structure of the area requiring repair:
 - Monolithic or sandwich structure
 - Material of original lay-up
 - Number of plies in original lay-up
 - Orientation of plies in the original lay-up
 - Thickness of plies in original lay-up
 - Extent of damage to the structure
 - Operational environment parameters
- ?? Determine the repair configuration
 - Monolithic or sandwich structure
 - Identify preferred repair material
 - Identify preferred repair process
 - Identify the required number of repair plies
 - Identify the best orientation of the repair plies
 - Accomplish analysis to confirm that this is an acceptable repair proposal

The analysis methods will address the following :

- ?? Perform a classical analysis of the original lay-up.
 - Calculate the stiffness and strength
- ?? Perform a classical analysis of the planned repair lay-up.
 - Calculate the stiffness and strength
 - Match original stiffness or stay just below this original value.
 - The strength should be the same or greater as the original value.

- ?? Compare the values of the original lay-up with the values of the repair lay-up.
- ?? Evaluate the stiffness (and perhaps also strength) of the repair as compared to the original laminate.
 - Stiffness should be at or below that of the original laminate.
 - Strength should be at or above that of the original laminate if possible.

Using coupons tested in Tasks 1 and 2, several available models will be evaluated ranging from simplistic to advanced (FEM). Levels of conservative will be assigned to each analysis methods as it corresponds to the experimental results.



Figure (1). Examples of damage experienced during service.

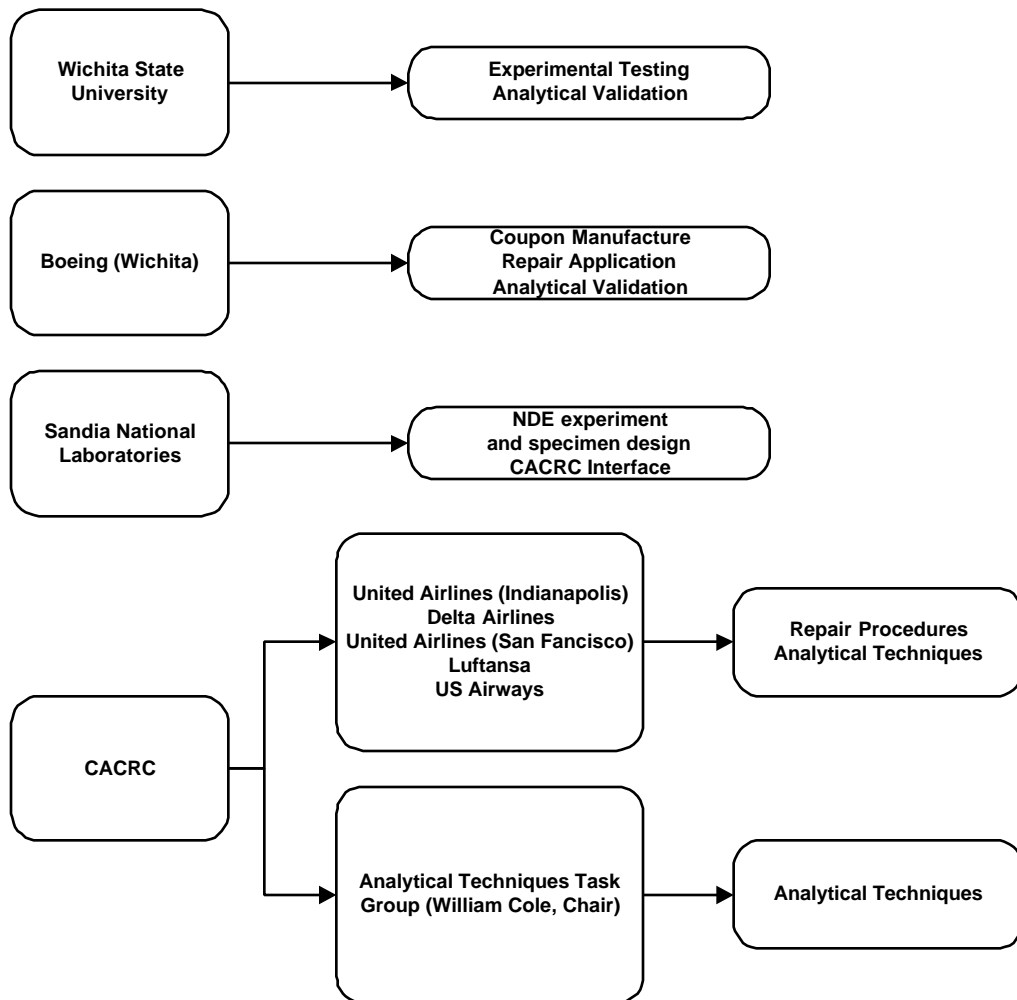


Figure (2). Investigation research partners and participating role.